

Dual RNA regulatory control of a *Staphylococcus aureus* virulence factor.

Svetlana Chabelskaya, Valérie Bordeau, Brice Felden

► **To cite this version:**

Svetlana Chabelskaya, Valérie Bordeau, Brice Felden. Dual RNA regulatory control of a *Staphylococcus aureus* virulence factor.. *Nucleic Acids Research*, Oxford University Press, 2014, 42 (8), pp.4847-58. <10.1093/nar/gku119>. <inserm-00944836>

HAL Id: inserm-00944836

<http://www.hal.inserm.fr/inserm-00944836>

Submitted on 11 Feb 2014

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

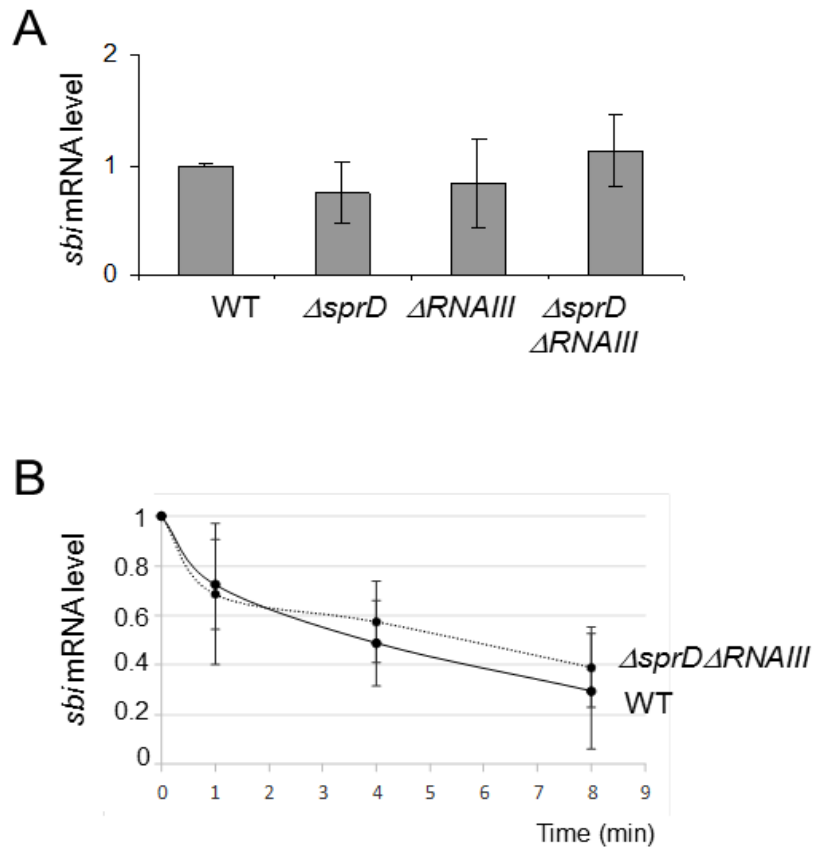
Dual RNA regulatory control of a *Staphylococcus aureus* virulence factor

Svetlana Chabelskaya, Valérie Bordeau, and Brice Felden.

Author affiliation: Université de Rennes 1, Inserm U835-UPRES EA 2311, Biochimie Pharmaceutique, 2 avenue du Prof. Léon Bernard, 35043 Rennes, France.

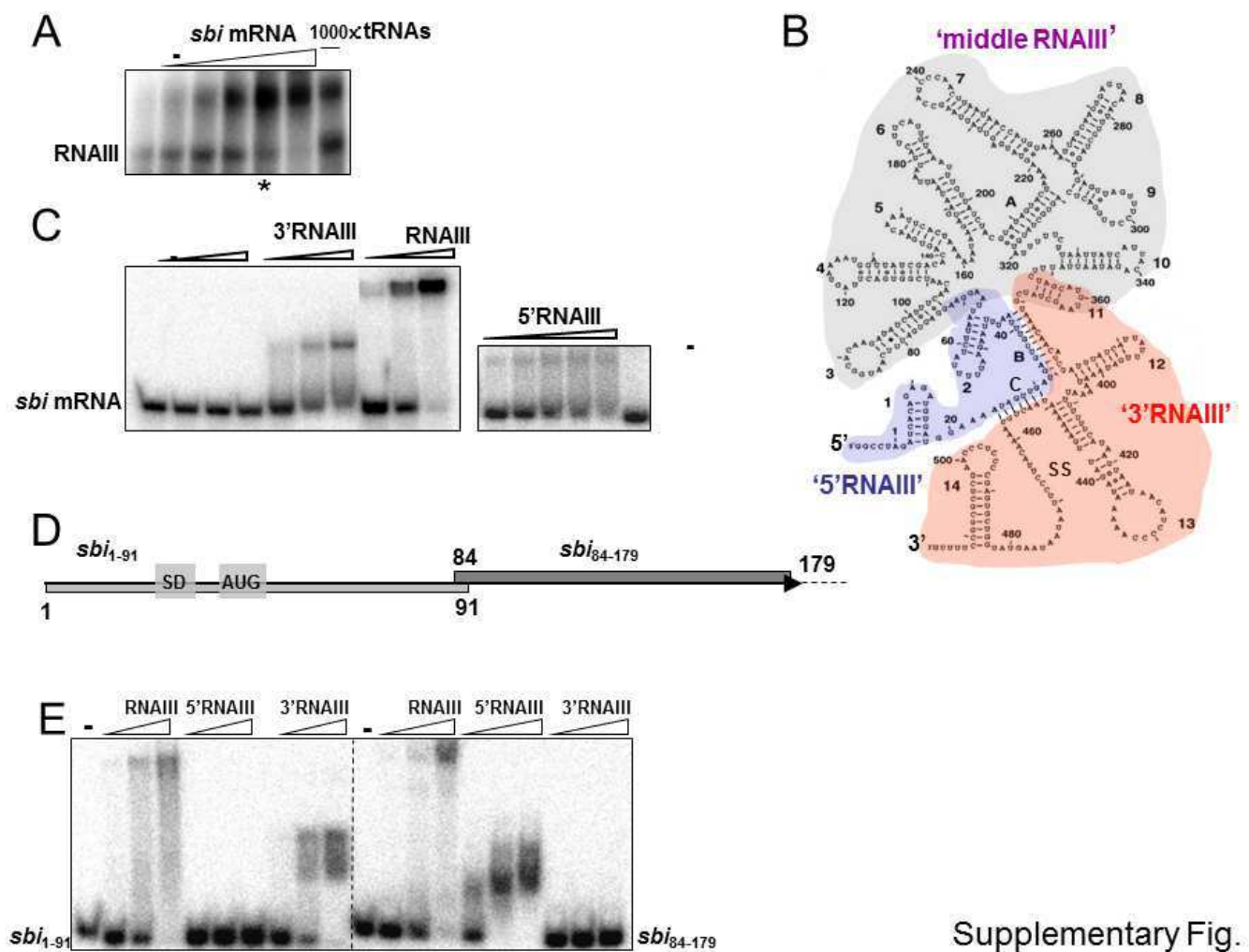
Corresponding author: Brice Felden, Université de Rennes 1, Inserm U835-UPRES EA 2311, Biochimie Pharmaceutique, 2 avenue du Prof. Léon Bernard, 35043 Rennes, France. E-mail: bFelden@univ-rennes1.fr.

Supplementary data



Supplementary Figure 1. RNAIII and SprD RNAs do not control Sbi expression at the RNA level. (A) Quantification by PCR of the *sbi* mRNA levels at the E phase (OD_{600nm} : 3) in wild-type (wt) and in $\Delta sprD$, $\Delta rnaIII$ and $\Delta sprD\Delta rnaIII$ *S. aureus* HG001 isogenic deletion strains. Both, SprD and RNAIII, are expressed at this growth point (Figures 1B and 1D). The *sbi* mRNA expression levels of the three mutants were calculated relative to the value measured for the wt strain. The error bars indicate the mean values derived from three independent experiments. For the quantitative real-time PCR (qRT-PCR), cDNAs were prepared using a High Capacity cDNA Reverse Transcription Kit (Applied Biosystems). qRT-PCR experiments were performed using RealMasterMix SYBR ROX (5 PRIME) with the primers listed in Supplementary Table 2. Three independent experiments were performed, with independent RNA purifications. The *hu* and *ssrA* genes were used for normalization. (B) Evaluation of the half-life of *sbi* mRNA in the strains HG001 (WT) and HG001 $\Delta sprD\Delta rnaIII$ ($\Delta sprD\Delta rnaIII$).

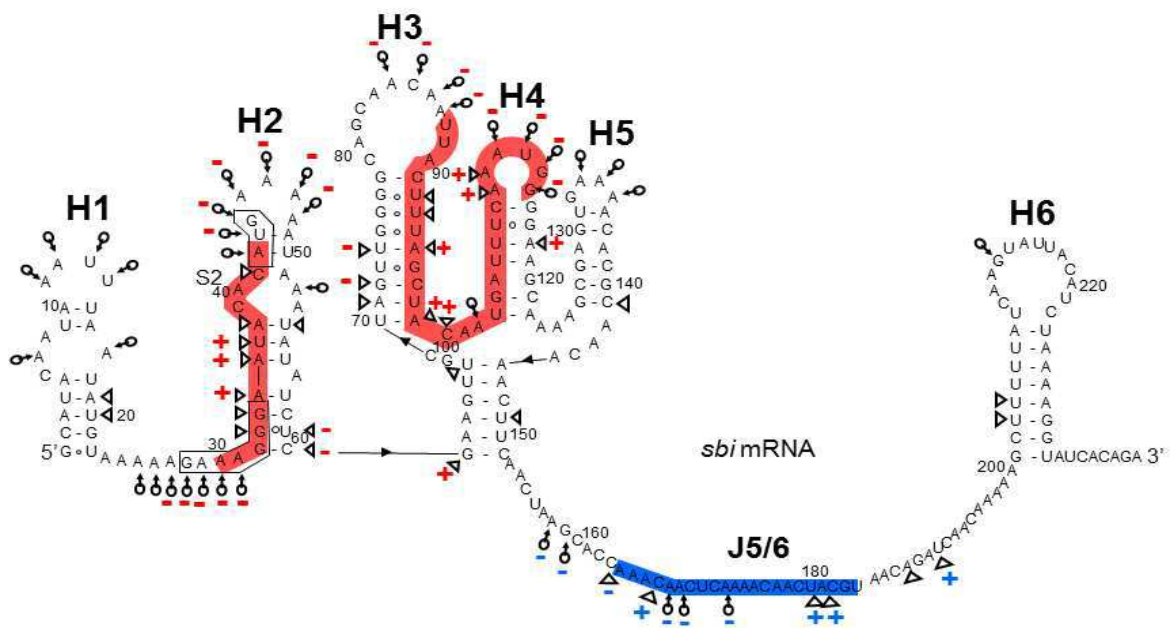
sbi mRNA half-life was measured in the presence of rifampicin (200 mg/ml) at mid-exponential growth phase (after 4h of growth). qRT-PCR conditions were as for panel (A). The half-life was given as the time where 50% of the RNA was degraded. Four independent experiments were performed, with independent RNA purifications.



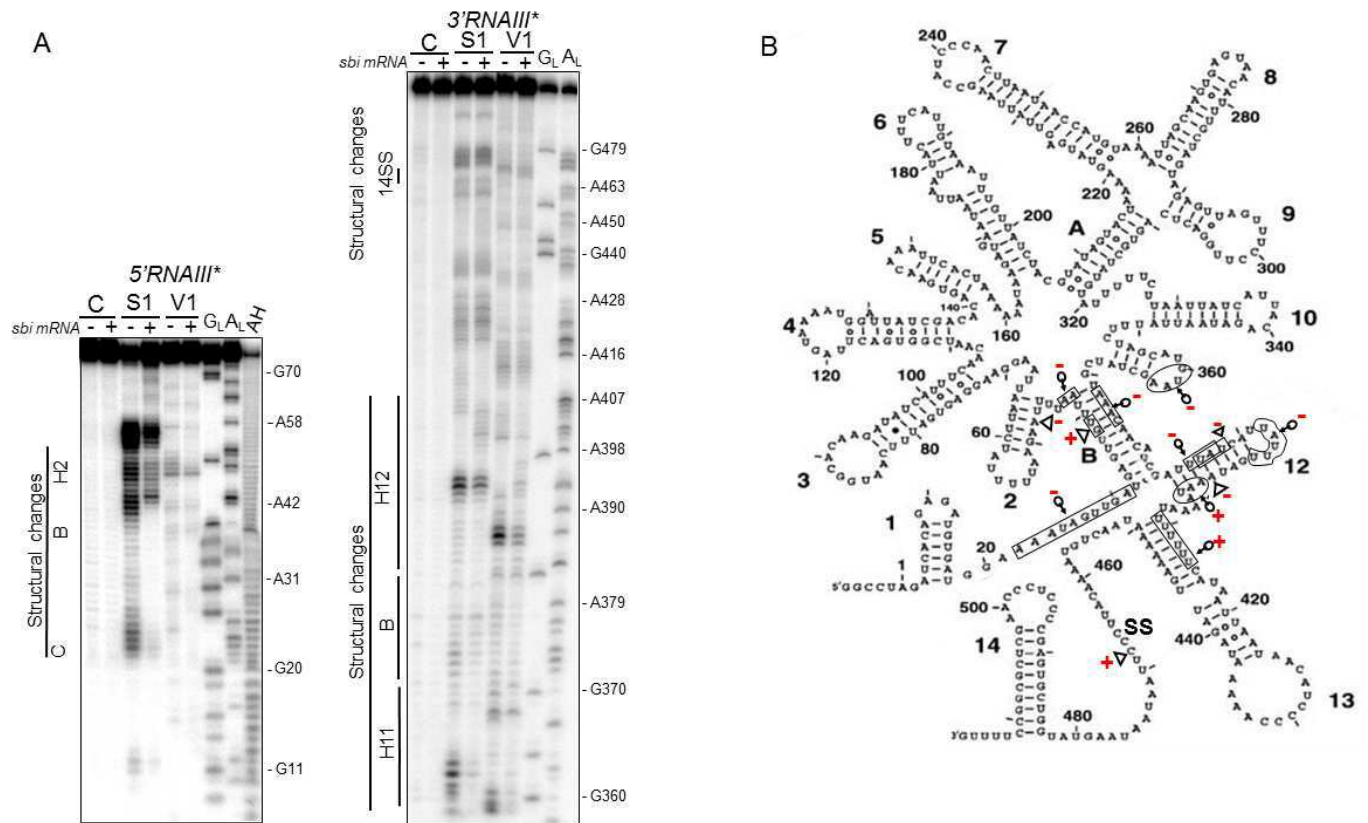
Supplementary Fig. 2

Supplementary Figure 2. RNAIII 5' and 3' domains interact at distinct sites on *sbi* mRNA. (A) Native gel retardation assays of labeled RNAIII with increasing amounts of unlabeled *sbi*₁₋₁₇₉ mRNA (0.1, 0.2, 0.5, 1 and 2 μ M). The asterisk indicates the *sbi* mRNA/RNAIII molar ratio used to perform the competition assays with a 1000-fold molar excess of total yeast tRNAs. (B) Deletion mutants constructed from and presented on the RNAIII secondary structure. 'middle RNAIII' is grey and corresponds to stem-loops 3-11 (grey), 5'RNAIII is blue and contains stem-loops 1-2 with half B and half C, and 3'RNAIII is red and encloses stem-loops 11-14. (C) Both its 5'- and 3'-domains are involved in RNAIII's interaction with *sbi* mRNA. Native gel retardation assays were used to show complex formation between labeled *sbi* mRNA and: full-length RNAIII (RNAIII; 0.1, 0.5 and 2 μ M,

left to right); 3'-domain (3'-RNAIII; 0.1, 0.5 and 2 μ M,); central domain (Middle RNAIII; 0.1, 0.5 and 2 μ M,); or 5'-domain (5'-RNAIII; 0.1, 0.2, 0.5, 1 and 2.5 μ M). (D) Schematic representation and location of the *sbi*₁₋₉₁ and *sbi*₈₄₋₁₇₉ constructs on *sbi* mRNA. Only *sbi*₁₋₉₁ contains the translation initiation signals. (E) RNAIII 3'-domain binds at the 5'-end of the *sbi* mRNA, while the 5'-domain of RNAIII interacts with the 3'-end of the *sbi* mRNA fragment. Native gel retardation assays were used to show complex formation between purified labeled 1-91 nts *sbi* mRNA (*sbi*₁₋₉₁*) or 84-179 nts *sbi* mRNA (*sbi*₈₄₋₁₇₉*) constructs with increasing amounts (0.2, 1.0 and 2.5 μ M) of unlabeled full-length RNAIII, 5'-RNAIII or 3'-RNAIII.

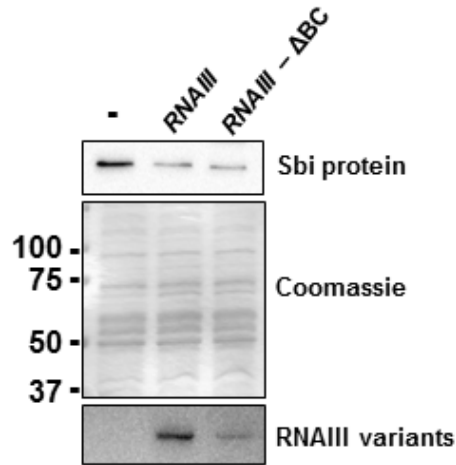


Supplementary Figure 3. The 5'-secondary structure of *sbi* mRNA. Secondary structure model of the *sbi* mRNA 5'-end (nts 1-238) of *S. aureus* strain N315. Solution probing data provided experimental support for the proposed structure. A conformation of only 62 nucleotides from the *sbi* mRNA 5'-end was already reported (Chabelskaya *et al*, 2010). Since the RNAIII-*sbi* mRNA interactions are extensive and complicated, the probing data were collected for a longer *sbi* mRNA fragment. Triangles indicate V1 cuts; arrows capped by circles indicate S1 cuts. Shown are the structural changes induced by *sbi* mRNA binding of 5'RNAIII (blue), 3'RNAIII (red), and full-length RNAIII. The boxed nucleotides are the *sbi* mRNA TIS.

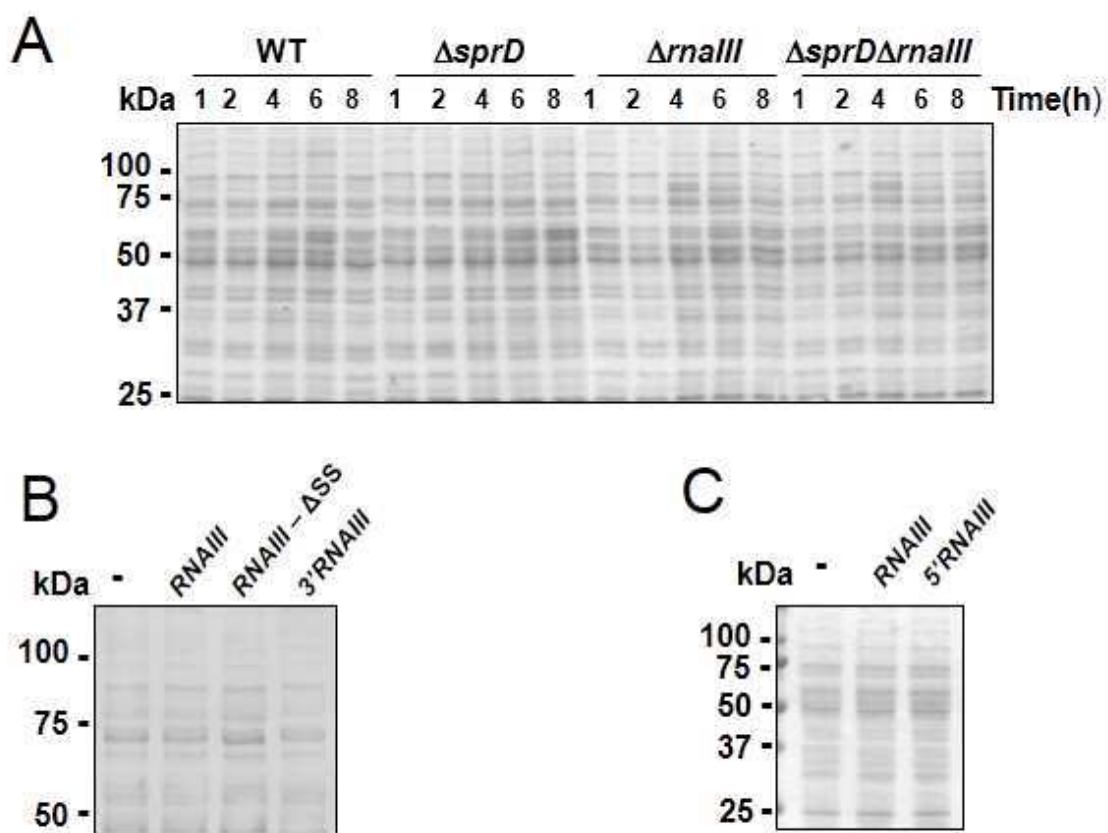


Supplementary Figure 4. Structural analysis of the conformational changes within the structure of RNAIII when in complex with *sbi* mRNA. (A) Conformational changes induced by the *sbi* mRNA on 5'RNAIII (left) or 3'RNAIII (right), detected by structural probes in solution. Shown are autoradiograms of the cleavage products of 5'-labeled RNAIII fragments by Nuclease S1 and RNase V1 in the presence (+) or absence (–) of *sbi* mRNA. Track C, incubation controls; track G_L, RNase T₁ hydrolysis ladders; track A_L, RNase U₂ hydrolysis ladders; track AH, alkaline hydrolysis ladders. (B) The RNAIII secondary structure (Benito *et al.* 2000) supported by the probing data presented in this report, showing the structural changes induced by complex formation with *sbi* mRNA. Triangles indicate V1 cuts; arrows capped by circles indicate S1 cuts. The structural changes induced by *sbi* mRNA binding with RNAIII are red, and the outlined nucleotides are those that are subjected to reactivity changes. Complex formation between *sbi* mRNA and 5'RNAIII induced structural changes located 22-44 nucleotides from the RNAIII 5'-end (part of stems B and C and H2). Binding between

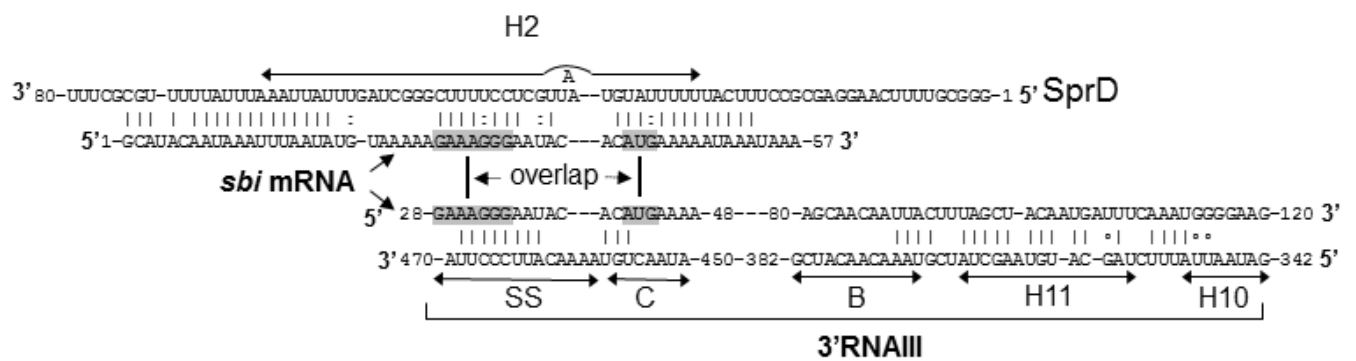
the *sbi* mRNA and 3'RNAIII induced structural changes located at loop 11, stem-loop 12, part of stem 13, and at SS.



Supplementary Figure 5. A *RNAIII-ΔBC* mutant is still able for governance of Sbi protein expression *in vivo*. The expression of protein Sbi at the exponential phase of growth in strain HG001 Δ *rnaIII* complemented with pCN38 Ω *RNAIII* (RNAIII) or pCN38 Ω *RNAIII-ΔBC* (RNAIII- Δ BC). Total protein amounts loaded and stained by Coomassie are shown. The lower panel depicts the Northern blot expression levels of RNAIII and mutant.



Supplementary Figure 6. Internal protein controls. Coomassie staining of the samples presented in Figures 1A (A), 6B (B) and 6C (C).



Supplementary Figure 7. Proposed pairings between the *sbi* mRNA translation initiation signals, *SprD*, and *RNAIII*. Pairings are based on the experimental data provided in this report and from our previous work (18). The structural domains of the two RNAs are indicated and the gray highlighting corresponds to the *sbi* mRNA TIS.

Supplementary Table 1. Strains used in and constructed for this study

<i>E. coli</i>		References
DH5 α	F ϕ 80 Δ <i>lacZ</i> Δ <i>M15</i> Δ (<i>lacZA-argF</i>) <i>U169 deoR recA1 endA1 hsdR17</i> (<i>r_K⁻ m_K⁻</i>) <i>phoA supE44 λ⁻ thi-1 gyrA96 relA1</i>	3
<i>S. aureus</i>		
RN4220	Restriction-defective derivative of 8325-4	4
HG001	<i>rsbU</i> restored strain 8325, lysogenic for phages ϕ 11, ϕ 12, and ϕ 13	5
HG001 Δ <i>rnaIIIa</i>	HG001 deleted for <i>rnaIII</i> by homologous recombination	2
HG001 Δ <i>rnaIII</i>	HG001 deleted for <i>rnaIII</i> ; <i>rnaIII::cat86</i>	This work
HG001 Δ <i>sprD</i>	HG001 deleted for <i>sprD</i>	This work
HG001 Δ <i>sprD</i> Δ <i>rnaIII</i>	HG001 deleted for <i>sprD</i> and <i>rnaIII</i> ; <i>rnaIII::cat86</i>	This work

Supplementary Table 2. DNA primers used in this study.

DNAs	Sequences	Purposes
Anti1640	GGCGCTCCTTGAAAACGCC	SprD Northern
NB3'RNAIII	TCAAATAATGATAAATCGATGTTGT	RNAIII Northern
T7RNAIIIfor	<u>TAATACGACTCACTATAGGGCCTAGATCACAGAGATGT</u>	RNAIII transcription
T7RNAIIIrev	CAAAAGGCCGCGAGCTTGGGA	
SBIforTR	<u>TAATACGACTCACTATAGGCATACAATAAATTTAATATGTAA</u>	<i>sbi</i> mRNA transcription, toeprint
SBIrevTR179	GTTGTTTTGAGTTGTTGGTGCT	
SbiT7rev238	TCTGTGATACCTTTTAGATGTA	
T7rev_Sbi_5'90	GTAATTGTTGCTGCCCAACT	<i>sbi</i> ₁₋₉₁ transcription
SBIT7delta84	<u>TAATACGACTCACTATAGGCAATTACTTTAGCTACAAT</u>	<i>sbi</i> ₈₄₋₁₇₉ transcription
RNAIII1_2rev	CTTCCTTAATTAAGATAAAAATTC	5'RNAIII transcription
RNAIII11_14for	<u>TAATACGACTCACTATAGGGCTAGCATGTAAGCTATCGTAAACAACA</u>	3'RNAIII transcription
RNAIII2_10for	<u>TAATACGACTCACTATAGGGGTAATTAAGGAAGGAGTGATTTC</u>	'middle' RNAIII transcription
RNAIII3_11rev	GATAGCTTACATGCTAGAAATAAT	
Revdelta14	CAGTTATTTTTTCAATCTATTT	RNAIII-ΔSS&14 mutation, for <i>in vitro</i> transcription
D14_mut_tb14rev	CAAAAGGCCGCGAGCCTTTCCTTTGCTCACGACCATACTTATTA	RNAIII-lutL14 mutation, for <i>in vitro</i> transcription
D14ssfor	ATAGATTGAAAAAATAACTGTAAAAAATAATAAGTATGGTCGTGA	RNAIII-ΔSS mutation, for <i>in vitro</i> transcription and <i>in vivo</i> expression
D14ssrev	TCACGACCATACTTATTATTTTTTACAGTTATTTTTTCAATCTAT	
RNAIIIdeltaBC	TAATACGACTCACTATAGGGCCTAGATCACAGAGATGTGATGGTTAAGAATTTTTATC TTAATT	'RNAIII-ABC' RNAIII transcription
rnaIIIDelta_11_12_for	AATTATCATTACAGATAATTATAAACAACATCTTTTTTTCATAATTAATAACA	'RNAIII-Δ11,12' RNAIII transcription
rnaIIIDelta_11_12_rev	TGTTATTAATTATGAAAAAAGATGTTGTTTATAATTATCTGTAATGATAATT	
RNAIII3EcoRI	AGTAGGAATTCCAACGCGAAAATATACCTGTAT	RNAIII plasmid

RNAIII5PstI	AGTTCTGCAGATACGTGGCAAACACTGGTCAAT	
new3'11_12_13_14_for	AGCATGTTTTTAATATAACTAGTTATCATTACAGATAATTATT	<i>in vivo</i> 3'RNAIII expression
new3'11_12_13_14_rev	AATAATTATCTGTAATGATAACTAGTTATATTTAAAACATGCT	

References

1. Benito Y, Kolb FA, Romby P, Lina G, Etienne J, Vandenesch F (2000) Probing the structure of RNAIII, the *Staphylococcus aureus agr* regulatory RNA, and identification of the RNA domain involved in repression of protein A expression. *RNA* 6:668–679.
2. Chabelskaya S, Gaillot O and Felden B (2010) A *Staphylococcus aureus* small RNA is required for bacterial virulence and regulates the expression of an immune-evasion molecule. *PLoS Pathog* 3;6(6):e1000927.
3. Sambrook J, Fritsch EF and Maniatis T (1989) *Molecular Cloning: A Laboratory Manual*. Cold Spring Harbour Laboratory Press, New York.
4. Kreiswirth BN, Löfdahl S, Betley MJ, O'Reilly M, Schlievert PM, Bergdoll MS, Novick RP (1983) The toxic shock syndrome exotoxin structural gene is not detectably transmitted by a prophage. *Nature* 305:709-712.
5. Herbert S, Ziebandt AK, Ohlsen K, Schäfer T, Hecker M, Albrecht D, Novick R, Götz F (2010) Repair of global regulators in *Staphylococcus aureus* 8325 and comparative analysis with other clinical isolates. *Infect Immun.* 78(6):2877-89.